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Integrating Circular Economy and Supply Chain Resilience: A Systematic Literature Review and Future Research Directions

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Abstract: ***Amid growing disruption risks and sustainability pressures, there is increasing interest in integrating circular economy (CE) principles with supply chain resilience (SCR) strategies. This paper presents a systematic literature review (SLR) of research at the integration of CE and SCR. We analyze conceptual and empirical studies to identify how circularity and resilience interact within supply chain management. The review reveals that circular supply chain practices – such as product redesign for reuse, localized recycling loops, and resource recovery – can simultaneously enhance resilience by reducing dependence on virgin materials and improving adaptive capacity (Gaustad et al., 2018; Paul & Saha, 2025). However, integrating CE and SCR also entails trade-offs; for example, closed-loop supply chains introduce new uncertainties (e.g., variable return flows) that must be managed to avoid eroding resilience (De Arquer et al., 2023). We synthesize the literature into key thematic categories: (1) synergistic practices that advance both circularity and resilience, (2) tensions and challenges in aligning CE and SCR goals, and (3) enabling factors (e.g., collaboration, digital technology) that support their integration. Drawing on these insights, we propose a comprehensive agenda for future research, including the development of integrated performance metrics, exploration of multi-tier collaborative frameworks, longitudinal studies of CE–resilience dynamics, and novel decision-support methodologies. The paper offers theoretical contributions by bridging sustainability and risk-management paradigms, and practical guidance for firms seeking to build supply chains that are both sustainable and shock-resilient.***

Keywords: circular economy; supply chain resilience; circular supply chains; sustainable supply chain; systematic literature review; sustainable operations; risk management; closed-loop supply chain

I. INTRODUCTION

In recent years, supply chains have faced unprecedented challenges – from global pandemic lockdowns to geopolitical conflicts and climate-induced disruptions – highlighting the critical importance of supply chain resilience (SCR). SCR refers to the ability of a supply chain to prepare for, respond to, and recover from disruptions while maintaining functionality (Ponomarov & Holcomb, 2009). Traditionally, firms have improved resilience through strategies like building buffer stocks, multi-sourcing, and flexible logistics. Meanwhile, mounting environmental concerns have spurred interest in the circular economy (CE) paradigm, which seeks to "design out" waste and keep products and materials in use through practices such as reuse, recycling, and remanufacturing (Kirchherr et al., 2017; Stahel, 2016). The CE stands in contrast to the linear "take-make-dispose" model by aiming to create regenerative, closed-loop systems that achieve sustainable development outcomes – economic, environmental, and social – for current and future generations. Each of these domains, SCR and CE, has grown into a significant area of research in supply chain management. However, until recently they largely evolved on parallel tracks with limited cross-fertilization (Stone & Rahimifard, 2018). This study addresses the emerging intersection of CE and SCR, examining how circular economy principles and practices can contribute to supply chain resilience (and vice versa) in pursuit of supply chains that are both sustainable and robust.

Integrating circularity with resilience is intuitively appealing: a circular supply chain inherently reduces reliance on virgin inputs and global sourcing by recirculating materials, which could mitigate exposure to supply shocks (Gaustad et al., 2018; Rasi et al., 2023). For example, Gaustad et al. (2018) have shown that recycling and material recovery strategies can safeguard manufacturers against critical raw material shortages, effectively enhancing resilience by "regenerating resources instead of procuring new ones." Likewise, recent events have illustrated potential synergies. During the COVID-19 pandemic, companies with circular business models (e.g., those investing in repair and refurbishment infrastructure and localized reuse of materials) reported significantly lower losses from supply disruptions than their traditional counterparts – one survey in Belgium found **66%** of circular-oriented firms

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suffered no losses during lockdowns, compared to only **2%** of non-circular firms (Ellen MacArthur Foundation, 2022). These cases suggest that circular economy practices such as modular product design, reuse of returned products, and local recycling can act as resilience levers by creating additional buffers and flexibility in supply networks (for instance, additional stock from returned items or alternative sourcing via recycled inputs). Such synergistic outcomes position CE as a strategic avenue to bolster resilience while also advancing sustainability goals. Policymakers and industry leaders have begun to recognize this **circular–resilient nexus**; for instance, the Ellen MacArthur Foundation notes that a circular economy reduces dependence on raw materials and *"increases the resilience and adaptability of supply chains"* (Ellen MacArthur Foundation, 2022).

At the same time, coupling CE with SCR is not without challenges. Researchers caution that circular supply chains introduce new complexities and uncertainties that can create tensions between efficiency and resilience if not properly managed (Scholten & Schilder, 2015; De Arquer et al., 2022). Closed-loop supply chains must handle uncertain timing and quality of product returns, additional processing steps for recycling/remanufacturing, and greater coordination across the reverse logistics network. These factors can make supply chain planning more difficult and, if systems are optimized strictly for lean efficiency (e.g., minimal inventory or just-in-time collection of returns), the network may become more fragile in the face of demand spikes or disruptions (Ivanov et al., 2014). For example, a recent study found that tuning a closed-loop supply chain purely for cost efficiency (using a proportional order-up-to inventory policy) worsened its ability to absorb sudden demand shocks, indicating a trade-off where *"optimizing efficiency may be problematic in terms of resilience"* (de Arquer et al., 2022, p.1319). Thus, one must balance the benefits of circularity for resilience (like resource security and supply flexibility) with potential drawbacks (like increased process complexity or uncertainty in reverse flows). Understanding these trade-offs is crucial for designing strategies that do not inadvertently undermine resilience in pursuit of circular economy gains.

Despite these challenges, the overarching consensus in emerging literature is that integrating CE and SCR holds great promise for developing robust, sustainable supply chains, provided that managers adopt a holistic approach. Several recent case studies and conceptual frameworks demonstrate how certain practices and capabilities can jointly promote circularity and resilience. These include product (re)design for durability and easy disassembly – which facilitates both reuse (a circular outcome) and faster recovery/repair in disruptions (a resilience outcome); process innovations and waste-to-resource initiatives that reduce environmental impact while creating fallback inventory (e.g., maintaining recycled materials stock as backup supply); supply network reconfiguration toward more localized and diversified loops to decrease dependency on distant suppliers and improve adaptive capacity; and inter-firm knowledge sharing and collaborative relationships that enable coordinated responses to disruptions and collective progress toward circular goals (Chari et al., 2022; Carissimi et al., 2024). Digital technologies such as Internet of Things (IoT) sensors and blockchain are also identified as enablers, improving visibility and traceability of materials in circular flows, which in turn enhances risk monitoring and responsiveness (Wang et al., 2020).

Given the nascent state of this interdisciplinary field, a systematic review is needed to consolidate what is known about the CE–SCR linkage and to chart future directions. Some preliminary literature reviews exist on circular supply chains (e.g., Rasi et al., 2023) and on supply chain resilience strategies (e.g., Rajesh, 2021), but a focused synthesis at the intersection of circular economy and resilience in supply chains has only just begun to appear (Le et al., 2025). This paper seeks to fill that gap by addressing the following objectives: **(1)** systematically review the extant literature (conceptual, empirical, and modeling studies) that explicitly links CE and SCR, **(2)** identify key thematic categories or frameworks describing how circular economy and resilience interact in supply chains (including both positive synergies and potential conflicts), **(3)** distill insights on methodologies and theoretical perspectives used, and **(4)** propose a robust agenda for future research that will advance understanding and guide both scholars and practitioners. In doing so, we aim to contribute to supply chain management theory by integrating two critical paradigms – sustainability (via circular economy) and risk management (via resilience) – and highlighting underutilized theoretical lenses that can explain their intersection. Practically, our findings and recommendations intend to support managers in designing supply chain strategies that achieve the dual goals of circularity (closing resource loops, eliminating waste) and resilience (absorbing and adapting to disruptions).

The remainder of this paper is structured as follows. First, we outline the methodology of the SLR, including the search and selection process and analysis approach. Next, we present the thematic findings of the review, organized into conceptual categories that characterize CE–SCR integration. We then discuss these findings in a broader context, noting theoretical contributions and practical implications. Based on identified gaps, we articulate several future research directions. Finally, we conclude with a summary of key insights and a call to action for further scholarly inquiry into circular and resilient supply chain management.

II. METHODOLOGY

To ensure a comprehensive and unbiased review, we followed a systematic literature review methodology grounded in established guidelines (Tranfield et al., 2003) and the PRISMA protocol for transparent reporting. The review process involved three main stages: planning, execution (literature search and selection), and synthesis.

Scope and Research Questions: In the planning stage, we defined the scope of the review around the central question: *"How have circular economy principles and supply chain resilience been integrated in the literature, and what are the key findings and gaps at this interface?"* From this, we derived sub-questions regarding conceptual linkages, empirical evidence of CE–SCR interactions, methodological approaches, and future research needs (aligned with our objectives in the Introduction). A review protocol was developed to detail the search strategy, inclusion/exclusion criteria, and analysis methods.

Literature Search: We conducted a systematic search for relevant studies in major academic databases including Web of Science, Scopus, Emerald Insight, and Google Scholar. The search terms combined keywords for circular economy and supply chain resilience, for example: *"circular economy" AND "supply chain"*, *"circular supply chain"*, *"closed-loop" AND "resilience"*, *"resilient" AND "circularity"*, etc. Additional synonyms and related terms (e.g., *"reverse logistics"*, *"supply chain risk"*, *"sustainable supply chain"*) were included to capture a broad set of literature. We limited the search to peer-reviewed journal articles and high-quality conference papers in English, with no region restrictions. Given that CE is a relatively recent concept in SCM, we considered publications from roughly 2000 up to mid-2025, capturing two decades of developments (with a focus on the surge of interest post-2015, when CE research in SCM grew rapidly).

Multiple rounds of searching were performed between March and June 2025. The initial search yielded approximately 150 documents. After removing duplicates, we had ~115 unique records. We then screened titles and abstracts against the inclusion criteria: studies had to explicitly address both circular economy (or closely related concepts like closed-loop supply chains, industrial symbiosis, etc.) and supply chain resilience (or related constructs like risk mitigation, disruption management). Papers focusing on only sustainability or only resilience without linking to CE were excluded. This screening filtered the set down to ~65 papers for full-text review.

Selection and Quality Assessment: Each of the candidate papers was read in full by at least two reviewers. We applied quality criteria to ensure the relevance and rigor of included studies: papers needed to have a clear discussion of CE in a supply chain context and some examination of resilience implications (or vice versa). We included conceptual frameworks, empirical case studies, simulation and modeling papers, and prior reviews that covered both topics. Through consensus discussions, we excluded studies that were only tangentially related (e.g., general sustainable supply chain management without CE specifics, or generic risk management without supply chain focus). This resulted in a final sample of $N \approx 45$ studies that form the basis of this review.

Data Extraction and Analysis: For each included paper, we extracted relevant information such as bibliographic details, supply chain context/industry, research design and methods, the specific CE practices or strategies examined, the resilience aspects or metrics considered, key findings regarding CE–resilience interaction, and any stated gaps or future research suggestions. We employed a content analysis approach to synthesize findings. First, we conducted open coding on the textual data (papers' findings and discussions) to identify recurring themes or concepts. These initial codes were clustered into higher-level categories through axial coding. For instance, codes related to *"use of recycled materials as backup supply"*, *"remanufacturing improving resource security"*, etc., were grouped under a broader theme of *"CE as an enabler of resilience."* We similarly identified themes around *"trade-offs and challenges," "integrated strategies/practices," "performance outcomes,"* and *"enablers of integration."*

To enhance reliability, two researchers coded a subset of articles independently and then reconciled differences, refining the coding scheme iteratively. We also performed a bibliometric analysis (using VOSviewer) to visualize co-occurrence of keywords and co-citation networks, which helped validate our theme identification by showing clusters of papers focusing on similar topics (for example, a cluster on CE and risk management). However, the primary analysis presented in this paper is qualitative and thematic. Where relevant, we incorporated quantitative insights (such as the number of studies in each theme, or distribution by year and industry). We also tabulated key studies to illustrate representative findings (see Table 1).

Tables and Figures: As part of the synthesis, we developed summary tables and figures. Table 1 highlights representative studies that explicitly examine circular economy–resilience links, detailing their context, methods, and key findings. This provides a quick landscape of existing research. Table 2 then summarizes the thematic categories we identified for how CE and SCR interact, along with illustrative references. We also include a conceptual framework diagram (Figure 1) adapted from the literature to visualize the integration of circular and resilient supply chain practices and their impact on performance. In the Discussion section, Table 3 outlines our recommended future research directions, tied to gaps identified in the literature. A methodological flowchart is also presented (Figure 2) to illustrate an example of a multi-method approach for studying CE–resilience strategies (as suggested in

emerging research). All information from sources is cited in APA style throughout, and a full reference list is provided at the end of the paper. Overall, our methodology ensured a systematic and reproducible review of the knowledge base at the CE–SCR nexus, lending confidence that the themes and conclusions drawn are grounded in the collective evidence of prior studies. Next, we turn to the results of this review – the thematic findings on integrating circular economy and supply chain resilience.

III. THEMATIC FINDINGS: INTEGRATING CIRCULAR ECONOMY AND SUPPLY CHAIN RESILIENCE

Our review of ~**45** studies reveal a multifaceted but still emerging body of knowledge on how circular economy and supply chain resilience intersect. We organize the findings into several conceptual themes that characterize this intersection: **(1)** circular strategies as enablers of resilience, **(2)** trade-offs and challenges in aligning circularity with resilience, **(3)** integrated practices and capabilities that synergistically advance both goals, and **(4)** performance outcomes and measurement of circular–resilient initiatives. Within each theme, we synthesize key insights and provide illustrative examples from the literature. Table 2 provides a summary of these themes, and Table 1 (below) lists representative studies with their context and findings.

Table 1. Key studies examining the integration of circular economy (CE) and supply chain resilience (SCR). Each study illustrates how CE principles/practices can influence SCR and vice versa.

Study	Year	Context/ sector	Methodology	Key findings on CE–SCR link
Bag et al. (2019)	2019	Manufacturing firms (South Africa; multi-sector sample)	Survey (n≈150) with SEM; tests moderating orientations	Dynamic remanufacturing capability is positioned as a CE-enabled capability that positively influences supply chain resilience, with effects shaped by managerial orientation/context.
Chari et al. (2022)	2022	Manufacturing supply chains; CE + resilience + Industry 4.0 emphasis (European context via project)	3-stage qualitative design: literature review + European project + nine expert interviews; proposition-building	Positions dynamic capabilities as enabling circular and resilient manufacturing supply chains; proposes a DC model and links resilience, CE implementation challenges, and Industry 4.0 enablers.
Cobra et al. (2023)	2023	Healthcare equipment supply (Brazil; COVID-19 crisis)	Case-based analysis of a voluntary public–private partnership and repair initiative	Repair (as a circular strategy) increased ventilator availability and is framed as bolstering health system resilience during crisis conditions; provides conditions/recommendations for viability.
Fletcher et al. (2021)	2021	Seafood sector business models (UK / broader seafood systems framing)	Framework development + literature-based application to seafood business models (CERF-BM)	Develops a "Circular Economy–Resilience Framework for Business Models (CERF-BM)" and argues seafood businesses' resilience can benefit from CE principles; highlights that many business models implement CE/resilience only partially.
Paul & Saha (2025)	2025	Electronics / smartphone distribution system	Quantitative modeling + simulation of demand-change scenarios	Quantitatively evaluates repair/reuse as circular strategies to mitigate demand shocks; models show improvements in resilience-related outcomes such as demand fulfillment and profitability under volatility.
Vimal et al. (2024)	2024	Circular sharing network (cross-industry framing)	AHP-based framework development + sensitivity analysis	Proposes an integrated decision framework to evaluate and prioritize resilience and sustainability practices in a circular sharing network; emphasizes real-time data collection and material synergy for resilience/sustainability.
Carissimi et al. (2024)	2024	Circular supply chain management (CSCM) practices; general SCM	Interpretive Structural Modeling (ISM) + MICMAC	Explicitly examines CSCM practices affecting sustainability and resilience; argues resilience can be enhanced through localization, digitalization, and collaboration; identifies "priority" practices (e.g., product-as-a-service) that drive performance.

Study	Year	Context/ sector	Methodology	Key findings on CE–SCR link
D'Adamo & Lupi (2021)	2021	Fashion industry (post-COVID framing)	Commentary/editorial-style argument	Frames circular economy transition as part of post-COVID sustainability/resilience discussion in fashion; introduces "circular premium" concept.
Ellen MacArthur Foundation (2022)	2022	Global trade & supply chains (cross-sector; policy/business analysis)	Official report/article synthesis	Argues circular economy is an avenue to tackle supply chain fragility exposed by global disruptions; positions circularity as reducing vulnerability by changing material flows and dependence patterns.
Le et al. (2025)	2025	CE–SCR intersection across SCM literature	Two-stage method: informal manager interviews + SLR (175 peer-reviewed papers) + bibliometric & content analyses	Identifies five practice families that jointly support circularity and resilience (product redesign, process improvement, network development, partner knowledge sharing, tech capability building) and emphasizes gaps in upstream collaboration, temporal dynamics, and integrated metrics.
de Arquer et al. (2022)	2022	Closed-loop supply chains (CLSCs)	Quantitative modeling/simulation of CLSC dynamics; examines efficiency vs resilience	Explicitly investigates how closed-loop designs and control policies can shift the efficiency–resilience balance; highlights overlap/ambiguity among resilience-related properties and motivates research on disruptions in CLSCs.
Aming'a et al. (2024)	2024	Manufacturing firms (Kenya; emerging economy)	Plant-level survey; SEM	Tests how "closed-loop supply chain models considering circular economy" influence "resilience sustainability" and sustainability dimensions; provides empirical evidence from an emerging economy context.
Torshizi et al. (2026)	2026 (early online 2025)	National-scale canned food supply network (omnichannel + reverse flows)	Integrated tri-objective optimization (profit, carbon, responsiveness) with disruption scenarios; validated in real application	Models circular economy decisions as endogenous levers that adapt under disruptions; positions CE as providing "built-in redundancy and resource recirculation," with results highlighting capacity flexibility as a major resilience driver.
Islam et al. (2025)	2025	Ready-made garments manufacturing (Bangladesh; emerging economy)	PLS-SEM (second-order hierarchical component model)	Finds CE practices partially mediate the relationship between big data analytics and supply chain resilience, suggesting digital capability → CE integration → stronger SCR.
Cafforio et al. (2025)	2025	Circular supply chains with take-back systems (fashion group case context)	Optimization-based framework computing post-disruption equilibrium; simulation across disruption scenarios	Proposes a CSC resilience definition that includes not only demand fulfillment but also continuity of circularity functions; evaluates how take-back strategy intensity affects resilience outcomes.
Jabbarzadeh et al. (2018)	2018	Closed-loop supply chain network design under disruptions	Stochastic robust optimization; includes lateral transshipment as reactive strategy	Develops a closed-loop network design model that performs resiliently under disruption/operational risks, emphasizing design-level choices (structure + transshipment) to preserve performance.
Vali-Siar et al. (2022)	2022	Mixed open-loop + closed-loop network; competition in recycling outputs	Network design with heuristic/metaheuristics; includes disruption and operational risks	Designs a resilient mixed open/closed-loop supply chain under operational and disruption risks; highlights the need to explicitly design resilience strategies and manage competitive dynamics in recycling flows.

(Sources: Compiled by the authors from the systematic review. In-text references above correspond to specific supporting studies in the literature.)

As illustrated in Table 1, studies across diverse industries (manufacturing, healthcare, food, electronics, fashion) consistently indicate that circular economy initiatives can bolster supply chain resilience – whether by providing alternative supply sources (through recycling or reuse), improving flexibility (through modular design and remanufacturing), or fostering collaboration and

knowledge sharing that aid disruption response. These studies also surface common challenges and success factors (e.g., need for supportive policies, balancing efficiency with redundancy, technology integration) which we elaborate in the thematic discussion below.

Table 2: Thematic summary of Circular Economy (CE) and Supply Chain Resilience (SCR) interactions, with key thematic categories and illustrative references.

Theme name	Definition	Mechanisms linking CE ↔ SCR	Illustrative references
Circular resource redundancy and input-risk buffering	Circular loops create substitute inputs/ components and alternative sourcing paths that reduce dependence on disrupted virgin-material flows	Remanufacturing/recycling/take-back systems provide secondary supply; localized recovery reduces lead-time exposure; reduces vulnerability to upstream scarcity	(Bag et al., 2019; Gaustad et al., 2018; Ellen MacArthur Foundation, 2022; Cafforio et al., 2025)
Repair/reuse for surge capacity and faster recovery	Extending product life and restoring functionality through repair/reuse improves continuity and recovery time during disruptions	Rapid repair programs restore critical assets; reuse reduces procurement delays; supports continuity of operations	(Cobra et al., 2023; Paul & Saha, 2025; Fletcher et al., 2021)
Dynamic capabilities and circular-resilient transformation	Organizational capabilities (learning, reconfiguration) enable coordinated adoption of CE and resilience practices	Dynamic capability building (often tech-enabled) supports reconfiguration, process change, and partner coordination required for circular-resilient systems	(Chari et al., 2022; Carissimi et al., 2024; Le et al., 2025)
Digital visibility and traceability as integration enablers	Digital tech improves information quality and coordination for both forward and reverse flows, enabling resilient circular operations	Analytics/traceability improves sensing, demand/return forecasting, and partner coordination; CE can amplify digital benefits through better closed-loop decisions	(Wang et al., 2020; Islam et al., 2025; Chari et al., 2022)
Network (re)design and omnichannel circularity under disruption	Designing networks to handle disruptions while managing reverse loops and omnichannel flows integrates CE decisions into resilience planning	Endogenous circular decisions under scenarios; facility siting and reverse handling choices create structural redundancy; capacity flexibility enables resilience	(Torshizi et al., 2026; Jabbarzadeh et al., 2018; Vali-Siar et al., 2022)
Trade-offs, complexity, and "new vulnerabilities" from circular loops	Circularity can increase structural/operational complexity and uncertainty (returns volume/quality, reverse lead times), potentially harming resilience if not controlled	Additional nodes/flows can amplify bullwhip-like dynamics; efficiency-focused policies can reduce shock absorption; circular strategies need balanced design	(de Arquer et al., 2022; Goltsos et al., 2019; Cafforio et al., 2025)

A. Circular Economy as an Enabler of Supply Chain Resilience

A dominant theme in the literature is that implementing circular economy practices often **enhances supply chain resilience**. In essence, circular strategies create additional slack and flexibility in supply chains that help firms survive and adapt to disruptions. Several mechanisms for this resilience benefit are identified:

1) Resource Looping and Redundancy: CE practices like recycling, remanufacturing, and reuse establish alternative flows of materials independent of virgin material supply. By "looping" products back into the supply chain, firms can rely on secondary (recovered) materials when primary supply is disrupted. For example, a manufacturer that collects and recycles critical components from end-of-life products has a redundant stock of inputs to draw on if new raw materials become scarce (Gaustad et al., 2018). This reduces dependency on volatile raw material markets and insulates the firm from supply shocks (Gaustad et al., 2018; Rasi et al., 2023). In this way, circular loops function akin to classic resilience tactics like safety stock or second sourcing – providing backup resources – but with the added benefit of waste reduction and resource conservation.

2) Local and Regional Sourcing through Circular Loops: Many circular economy models emphasize localized recovery and reuse of materials (e.g., community recycling programs, local remanufacturing facilities). This localization shortens supply lines and reduces exposure to global disruptions. During COVID-19, companies with local repair/refurbishment operations could maintain production using returned products despite international supply chain breakdowns (Ellen MacArthur Foundation, 2022). A circular supply chain inherently favors more distributed, decentralized networks (since collection and reprocessing often happen near consumers), which can improve resilience by avoiding single points of failure and enabling regional self-sufficiency in emergencies.

3) Inventory Buffer via Returns and "Waste-as-Resource": Several authors note that circular strategies can create a form of buffer inventory that boosts resilience (Paul & Saha, 2025). For instance, Paul and Saha's simulation (2025) demonstrates that a company practicing repair and reuse essentially holds a "hidden" inventory of used products that can be refurbished to meet a surge in demand. In their model, when demand spiked unexpectedly, the firm with a circular strategy was able to fulfill orders by repairing returned units, whereas a linear system without that buffer failed to meet demand. Similarly, waste from one process can be reclaimed as input for another (industrial symbiosis), effectively increasing material availability under stress. Thus, CE contributes to resilience by turning waste streams into useful stock that can be tapped when fresh supplies are limited.

4) Adaptive Innovation and Learning: Embracing circular economy often requires firms to innovate (e.g., new product designs, new business models like product-as-a-service) and to collaborate extensively with supply chain partners. This cultivates an organizational culture of flexibility and learning that is also conducive to resilience. Some studies frame this in terms of *dynamic capabilities* – the ability to sense, seize, and reconfigure resources in response to change (Chari et al., 2022). Circular initiatives force firms to rethink product life cycles and engage in continuous improvement (e.g., finding uses for by-products), which can make the organization more agile and adept at handling unexpected events. For example, companies that developed take-back and remanufacturing programs had to build new reverse logistics networks and partnerships; these same capabilities (asset recovery networks, partner coordination skills) proved invaluable in responding to disruptions (such as rapidly collecting and redeploying products during a recall). In essence, circular-oriented firms may inherently develop a more *agile and resilient mindset* at both operational and strategic levels.

Overall, the literature strongly supports the view that CE and SCR can be **mutually reinforcing**. By eliminating waste and creating closed loops, supply chains not only become more sustainable but also more shock-proof (Ridley, 2019). This synergy is evident both in quantitative studies (which show improved performance metrics under disruption scenarios when circular strategies are in place) and in qualitative accounts (where managers report that circular practices helped them navigate crises). As one policy review succinctly stated: *"Circular economy principles help supply chains adapt to and maintain operations amidst unforeseen disruptions, fostering sustainable growth and resilience"* (Ellen MacArthur Foundation, 2022). The COVID-19 pandemic has been a particularly illuminating "natural experiment" in this regard – firms with capabilities for reuse, recycling, and local production pivoted more easily to overcome supply interruptions and even discovered new business opportunities (e.g., repurposing recycled plastics to produce medical supplies when traditional sources were unavailable).

However, it must be noted that these resilience benefits of CE typically materialize only when certain conditions or complementary actions are present. For example, simply having access to recyclable material is not enough; the firm must also have the technical capacity and infrastructure to process those materials quickly into usable inputs (hence investment in appropriate technology and skills is important). Likewise, inter-firm collaboration is often crucial – a single company's circular program (say, collecting used products) might fail to deliver resilience benefits if upstream or downstream partners are not aligned or willing to cooperate (for instance, if suppliers do not accept recycled feedstock, or customers do not return products). These points lead into the next theme: the challenges and trade-offs that can complicate the CE–resilience relationship.

B. Trade-offs and Challenges in Aligning Circularity with Resilience

While circular economy practices offer clear potential to enhance resilience, researchers have also identified significant challenges, trade-offs, and potential unintended consequences when integrating the two paradigms. Three key areas of tension emerge:

1) Efficiency vs. Redundancy Trade-off: Classic resilience thinking often calls for redundancy (e.g., extra inventory, capacity, backup suppliers) to buffer against shocks, whereas circular economy and sustainability initiatives often emphasize efficiency and waste reduction. Implementing CE can involve streamlining resource use – for instance, using just-in-time collection of used products or minimizing idle stock by continuously cycling materials. If pushed to the extreme, these efficiency-oriented practices might reduce buffers that are useful in a crisis. Scholten and Schilder (2015) and others have noted that lean, tightly coupled systems (even circular ones) can be more fragile under certain conditions. One study on closed-loop supply chains

found that optimizing inventory control for cost efficiency led to worse resilience outcomes (de Arquer et al., 2022). Managers might be tempted to hold less virgin material inventory if they expect recycled material streams to cover needs, but if the returns are uncertain, they could end up with shortages. Thus, finding the *appropriate balance between efficiency and resilience* is critical (Ridley, 2019). Some authors refer to this as managing a "rebound effect" – e.g., cost savings from circular efficiency might be negated by new risks if not managed carefully. The implication is that firms should deliberately design circular systems with resilience in mind, perhaps by keeping strategic stockpiles of secondary materials or maintaining a mix of circular and linear sourcing options to hedge against uncertainties.

2) Uncertainty in Reverse Flows: A fundamental challenge unique to circular (closed-loop) supply chains is the uncertainty of returns – both in quantity and quality. Unlike traditional supply chains that can forecast demand and plan procurement with some accuracy, circular chains have to deal with stochastic return patterns (how many used products will come back and when?) and variability in the condition of returned items. Goltsos et al. (2019) highlight that this unpredictability in return flows adds a layer of complexity that can itself be a source of risk. For example, if a firm relies on remanufacturing returned units to fulfill orders, a delay or shortfall in returns could jeopardize its production schedule. Similarly, recycling processes might face quality issues if feedstock from waste streams is contaminated or inconsistent, potentially causing disruptions in downstream manufacturing that uses the recycled material. Managing these uncertainties requires advanced planning and flexibility – for instance, dynamic inventory control policies or flexible manufacturing lines that can switch between new and recycled inputs. Ivanov (2020) uses the term *"ripple effect"* to describe how disruptions propagate in supply networks; in circular networks, a disruption in returns collection (say, a lockdown halts product returns) can ripple forward just as a disruption in raw material supply would ripple backward. Thus, circular supply chains need resilience not just against external shocks but also against internal process variability. This challenge suggests that new forecasting models and responsive control systems are needed specifically for reverse logistics and circular flows to buffer against return-related uncertainties.

3) Complexity and Coordination Challenges: Circular supply chains often involve more complex networks and stakeholders than linear ones. For example, a circular model might include additional partners: recycling companies, refurbishers, secondary marketplaces, even consumers as suppliers of returns. Coordinating across this expanded network can be challenging. Upstream–downstream collaboration is frequently noted as a weak point in current practice (Le et al., 2025). Many firms operate CE initiatives in isolated pockets (e.g., a take-back program or recycling effort that is not fully integrated with suppliers or customers), which limits their effectiveness and could cause inefficiencies. For instance, if a manufacturer does not communicate its need for certain recyclable materials to suppliers, those suppliers might not invest in recovery infrastructure, leading to bottlenecks when trying to source recycled inputs. Rasi et al. (2023) identified multiple interdisciplinary challenges – spanning technical, organizational, and social aspects – that hinder circular adoption in supply chains, such as misaligned incentives among partners, lack of standardization for recycled materials, and regulatory barriers. These challenges can undermine resilience benefits if, say, legal restrictions prevent the quick redeployment of used components during an emergency (as was seen in some cases where medical device reuse was slowed by regulations). Cobra et al. (2023), for example, found that regulatory strictures and lack of trust among stakeholders were barriers when setting up a repair network for medical equipment. Essentially, achieving resilience through circularity requires system-wide implementation; partial or piecemeal circular efforts may not yield resilience and could even create new weak links (e.g., a poorly managed recycling supplier could become a single point of failure). Therefore, a recurring recommendation is to improve supply chain coordination, information sharing, and supportive policy frameworks to smooth out these complexities.

In summary, the literature urges a cautious, well-managed approach to marrying CE with SCR, acknowledging that trade-offs exist and must be explicitly addressed. The presence of tensions does not negate the overall synergy, but it means companies must redesign processes and control systems to handle the unique demands of circular operations. For example, flexible manufacturing systems that can accommodate both recycled and new materials can reduce the risk of variability. Strategic inventory of critical recycled inputs can counter uncertainty in returns (akin to holding safety stock). Scenario planning and simulation (as done by some researchers) can help anticipate where circular initiatives might introduce fragility, allowing firms to preemptively mitigate those risks (e.g., by having contingency plans if return rates drop unexpectedly). Overall, the key is to design *resilience into the circular model*, rather than assuming circularity automatically yields resilience. When done thoughtfully, the next theme shows that there are certain practices and capabilities that simultaneously drive circularity and resilience, effectively addressing many of these challenges.

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C. Integrated Practices and Synergistic Strategies

Through our review, we identified a set of practices, strategies, and capabilities that repeatedly emerged as important for achieving **both** circular economy objectives **and** supply chain resilience. These can be thought of as the "common ground" or overlap between CE and SCR in terms of actionable approaches. Notably, a recent comprehensive SLR by Le et al. (2025) compiled 64 distinct supply chain practices and 43 performance metrics related to circular and resilient supply chains, and highlighted five overarching categories of practices that support both goals. Building on that and other sources, we summarize the key integrated practices below:

1) Product (Re)Design and Innovation: Perhaps the most frequently cited category is designing products *for circularity* – including modular design, easy disassembly, durability, and upgradability. Such design choices facilitate reuse, repair, and remanufacturing (core CE activities), and at the same time improve resilience by making it easier to fix or adapt products during disruptions (Le et al., 2025). For example, a modular product architecture allows a manufacturer to swap out or upgrade faulty components quickly (useful if a certain part is in shortage) and also allows using refurbished modules as replacements. Modularity and standardization in design can thus shorten recovery times when failures occur (a resilience benefit) and prolong product life through upgrades (a circular benefit) (Stone & Rahimifard, 2018). In practice, companies like Fairphone (known for modular smartphones) exemplify this synergy: their phones are designed for easy repair (circularity) which also means users face minimal downtime from failures (resilience for the user and the supply chain). Innovation in materials (e.g., using recyclable or bio-based materials) also supports circularity and can reduce dependence on scarce inputs, thereby aiding resilience. In short, embedding circular principles at the design stage yields products and processes that are inherently more resilient to supply or demand shocks.
2) Process Improvement and Waste Reduction: Lean and agile process methodologies adapted for circular objectives are another synergy point. Many firms implementing CE engage in process improvements to eliminate waste (energy efficiency, water recycling, scrap reduction). These initiatives, when done intelligently, also streamline operations and build agility, thereby supporting resilience. For example, industrial symbiosis (one firm's waste becoming another's input) not only reduces waste sent to landfill but creates inter-firm ties that can be leveraged during disruptions (companies in a symbiosis network might support each other with materials in emergencies) (Vimal et al., 2024). Total quality management and maintenance programs aimed at extending equipment life (a form of circular thinking) also reduce breakdown risks and improve reliability (resilience). However, as discussed, care is needed to ensure that extreme leanness in processes doesn't remove necessary slack. The literature suggests focusing on "smart waste reduction" – eliminating non-value-added activities and materials while keeping adaptive capacity. Techniques like the *6R framework* (Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture) are promoted as they inherently combine process efficiency with circular reuse. In sum, process improvements that remove waste and inefficiency often lead to simpler, more transparent supply chains that are easier to control under stress, thus aiding resilience.
3) Supply Network (Re)Configuration and Development: A major strategic-level overlap is in supply chain network design. Circular supply chain management often involves developing new network structures – for instance, adding reverse logistics channels, working with local recycling partners, or creating secondary markets for used products. These actions, if planned well, can drastically improve resilience by diversifying sourcing options and shortening supply routes. One clear example is multi-sourcing: circular economy encourages sourcing from recycled material providers in addition to traditional virgin material suppliers. This inherently gives multiple supply sources (a resilience best practice). Likewise, setting up regional recycling or remanufacturing plants can reduce reliance on distant global suppliers and cut lead times, which improves responsiveness in disruptive events. The literature repeatedly mentions supplier diversification, localization, and collaboration as key enablers of circularity that align with resilience principles (Stone & Rahimifard, 2018; Rasi et al., 2023). Network development also includes engaging non-traditional partners like social enterprises for repair or municipalities for waste collection, expanding the ecosystem that can be called upon in a crisis. However, as noted, this comes with coordination complexity. The overall guidance is that companies should strategically design their supply networks to be circular (closed-loop) and resilient by structure – e.g., include backup suppliers for critical recycled inputs, maintain some regional self-sufficiency for key components, and build strong, trust-based relationships across the supply chain.
4) Knowledge Sharing and Partner Collaboration: Both CE and SCR literatures underscore the importance of collaboration and information sharing across the supply chain. For circular economy, knowledge sharing (e.g., sharing data on material composition, recycling techniques, demand for secondary materials) is crucial for creating efficient loops (Rasi et al., 2023). For resilience, sharing information (e.g., on inventory levels, disruption alerts, recovery plans) is a known best practice to coordinate responses. Many studies advocate for integrated platforms or forums where supply chain partners jointly plan

circular and resilient strategies. For instance, a "closed-loop supply chain council" involving suppliers, manufacturers, recyclers, and logistics providers can align objectives – such as designing products that suppliers can easily remanufacture, and agreeing on contingency plans for disruptions. Trust and long-term partnerships are repeatedly cited as enabling both CE implementation and effective crisis management (Cobra et al., 2023). In practical terms, collaboration might manifest in co-investments (e.g., a retailer and supplier co-invest in recycling facilities), risk-sharing agreements (such as take-back programs where costs and benefits are shared), or simply more frequent communication and joint decision-making. The theme here is that supply chain relationships should evolve from transactional to collaborative to simultaneously achieve circular reuse goals and resilience preparedness. Some authors link this to the concept of "joint dynamic capabilities," where networks collectively learn and adapt (e.g., a supply network's ability to reconfigure itself using shared knowledge in a disruption is greater when CE-oriented collaboration is in place). Interestingly, upstream collaboration in particular was noted as a gap – firms often focus on downstream recycling with customers but don't engage suppliers early; future efforts need to bring suppliers "into the loop" (literally) for both CE and SCR gains (Le et al., 2025).

5) Technological Capabilities (Digitalization and Analytics): The final major category involves technology and data-driven capabilities. A number of recent studies stress that digital technologies act as critical enablers for circular and resilient supply chains (sometimes termed "Supply Chain 4.0" or "Industry 4.0" in this context). Technologies like blockchain can provide traceability of products and materials throughout their life cycle, which helps in verifying recycled content, tracking asset conditions, and quickly identifying where parts are during recalls or disruptions (supporting fast response) (Wang et al., 2020). IoT sensors and RFID tags can monitor the use-phase of products and signal when and where items are ready for end-of-life collection, making reverse logistics more responsive and efficient (thus reducing uncertainty in returns, a resilience boost). Advanced analytics and AI can be used to predict return flow patterns (improving planning for remanufacturing) and also to optimize circular inventory and production in real-time when disruptions strike. For example, AI algorithms might dynamically allocate recycled material stock to where it's needed most in a supply shock scenario, or identify viable substitute materials from recycling streams when a primary material source is cut off. Big data from circular operations (e.g., data on product usage, failure rates, collection volumes) can feed into resilience risk models. Indeed, one case by Wang et al. (2020) demonstrated a blockchain-enabled system for a fast-fashion circular supply chain that improved both sustainability and resilience by enhancing transparency and trust among participants. In summary, building technological capabilities—digital infrastructure, data analytics, automation—amplifies the effectiveness of CE initiatives and strengthens resilience by enabling better visibility, anticipation of risks, and agile decision-making across the supply chain. Many authors call for more research on the use of such technologies in the CE–SCR context (Dubey et al., 2021), which we echo in our future directions.

Collectively, these integrated practices form a kind of toolkit for practitioners aiming to achieve circularity and resilience together. Figure 1 provides a visual depiction of how some of these elements interact in a circular–resilient supply chain framework, based on the synthesis of Le et al. (2025) and others. Essentially, by focusing on product design, process improvements, network configuration, collaboration, and technology, firms can create supply chain systems that are both regenerative (circular) and robust (resilient). It is notable that these practices do not operate in isolation but are often complementary. For instance, adopting modular product design (design practice) might require new agreements with suppliers (network collaboration) and investments in tracking components (technology). When combined, the result is a highly adaptable circular supply chain capable of withstanding shocks.

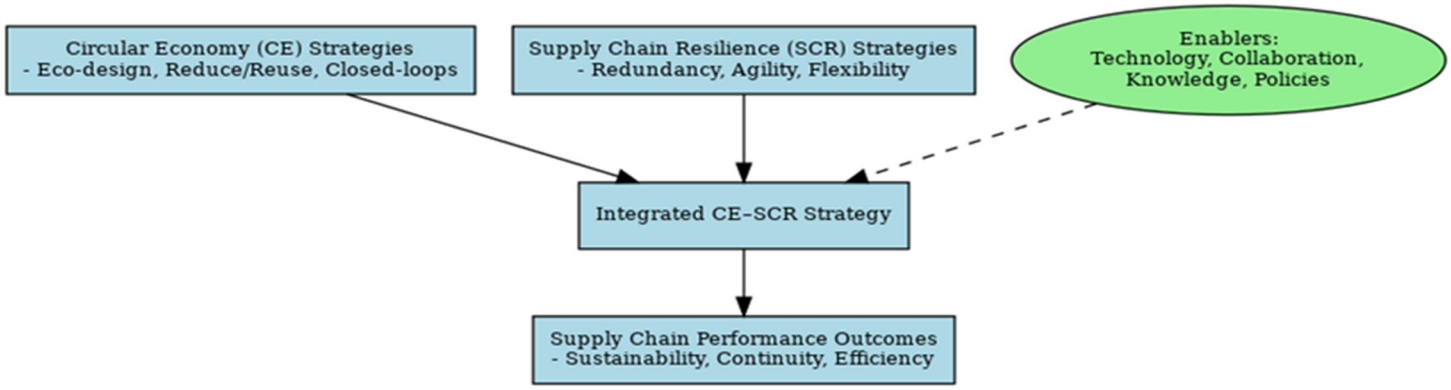

Figure 1. *Conceptual framework illustrating the integration of Circular Economy (CE) and Supply Chain Resilience (SCR) practices and their impact on supply chain performance. CE strategies (left, e.g., eco-design, reuse, recycling initiatives) and SCR*

strategies (left, e.g., redundancy, agility, flexibility measures) converge into an integrated CE–SCR approach (center). This integration is supported by various enablers (top) – such as technology, inter-firm collaboration, knowledge sharing, and supportive policies – which facilitate the alignment of circular and resilience efforts. The combined implementation of CE and SCR practices leads to improved performance outcomes (right), enhancing both sustainability (e.g., resource efficiency, waste reduction) and resilience (e.g., continuity of supply, faster recovery) in the supply chain. (Adapted from Le et al., 2025 and other sources)

In **Figure 1**, one can see that circular and resilient supply chain strategies are not only compatible but indeed reinforce each other when properly managed. For example, building flexible manufacturing capacity (a resilience practice) allows a plant to handle recycled materials or new products with equal ease, facilitating circular flows. Similarly, establishing redundant supply sources (a resilience practice) can include secondary (recycled) sources, thus furthering circular goals. The framework also highlights the need for performance measurement across all dimensions, which leads us to a brief note on outcomes and metrics.

IV. PERFORMANCE OUTCOMES AND THE NEED FOR INTEGRATED METRICS

Assessing the success of circular–resilient initiatives require looking at a range of performance outcomes. The literature notes that firms aim to achieve a *"triple win"*: economic gains, environmental benefits, and improved supply chain continuity (resilience). Many case studies report improved business performance (e.g., profitability, market share) as an outcome of integrating CE and resilience – often through cost savings from waste reduction plus avoidance of losses during disruptions (Fletcher et al., 2021). Environmental performance improvements (lower carbon footprint, less waste) are of course a direct goal of CE. Social performance (e.g., job creation in recycling, improved community well-being) is sometimes noted but less frequently quantified in SCR contexts.

However, a challenge identified is that companies and researchers lack standardized, integrated metrics to jointly measure circular economy **and** resilience performance (Le et al., 2025). Traditional key performance indicators for resilience include fill rate during disruption, time-to-recovery, and financial impact of disruptions. CE metrics include recycling rate, reduction in virgin material use, lifecycle emissions reduction, etc. Rarely are these measured together to see trade-offs or synergies quantitatively. Le et al. (2025) point out a gap in integrated performance evaluation, calling for development of combined metrics or scorecards that reflect both resilience and circularity. For instance, a *"circular resilience index"* could be conceived, incorporating factors like diversity of material sources (a resilience indicator) weighted by percentage of those sources that are recycled or renewable (a circular indicator). Some studies have begun to propose such frameworks (e.g., hybrid sustainability-resilience indices), but this remains an area for further work.

What the current literature does suggest is that integrated strategies tend to yield **positive outcomes across multiple dimensions**. For example, D'Adamo and Lupi (2021) note that firms see not just reduced environmental impact but also better risk management – a win–win that they term the *circular premium.* In Paul and Saha's simulation, using circular strategies improved profit and customer service levels while also reducing waste. Thus, when properly executed, circular–resilient practices do not appear to force a compromise between sustainability and traditional performance; rather, they contribute to long-term supply chain viability, which includes economic viability. This aligns with the broader argument that sustainability and resilience are complementary for enduring business success – a resilient supply chain can operate continuously and meet stakeholder needs (which is inherently more sustainable over the long run), and a sustainable (circular) supply chain inherently cultivates forms of resilience through resource security and community goodwill. In conclusion of the findings, we have seen that the literature provides evidence of synergy between circular economy and supply chain resilience, tempered by acknowledgment of challenges that need careful management. The thematic analysis underscores a range of strategies that can yield dual benefits, and points out where further research and managerial innovation are needed (e.g., in developing metrics, improving multi-tier collaboration, leveraging digital technology).

These findings form the foundation for our Discussion section, where we interpret the implications for theory and practice, and then outline specific future research directions to address the gaps identified.

V. DISCUSSION

The confluence of circular economy and supply chain resilience represents a promising frontier in supply chain management theory. Our review reveals that, conceptually, CE and SCR share underlying goals of long-term viability and adaptive efficiency – aligning environmental stewardship with the capability to withstand shocks. In this section, we highlight the theoretical contributions of integrating these domains, examine the practical implications for managers and policymakers, and delineate how our findings relate to or extend existing frameworks in the literature. We also acknowledge limitations of current knowledge and of our review, which motivate the future research directions proposed subsequently.

VI. THEORETICAL CONTRIBUTIONS

By systematically reviewing CE–SCR literature, this paper contributes to theory in several ways. First, it bridges two previously disparate streams of research – sustainable supply chain management (with an emphasis on circularity) and supply chain risk/resilience management – demonstrating that they are not only compatible but mutually reinforcing under a unifying framework. This integration answers calls from scholars to break down silos between sustainability and resilience research (Stone & Rahimifard, 2018; Xu et al., 2020). We show that concepts like redundancy, flexibility, and adaptability (from resilience theory) and concepts like resource efficiency, closed-loop systems, and life-cycle thinking (from CE theory) can and should be jointly considered. Our thematic findings provide a conceptual model (see Figure 1) that supply chain researchers can use as a basis for developing new theory – for example, theories about how knowledge-based dynamic capabilities enable firms to simultaneously pursue environmental and resilience outcomes, or how complex adaptive systems theory might describe a circular–resilient supply chain that self-organizes and evolves in response to disruptions. We find that certain theoretical lenses, such as dynamic capabilities, the resource-based view (RBV), and stakeholder theory, have begun to be applied (e.g., Bag et al. 2019 used RBV in a remanufacturing context; Chari et al. 2022 employed a dynamic capability perspective). Yet, there remains opportunity to further theorize the CE–SCR link using, for instance, ecological systems theory (drawing parallels between ecosystem resilience and industrial ecosystems in CE) or institutional theory (to explore how norms and regulations drive firms to integrate sustainability and resilience practices). Our review provides the groundwork by identifying key constructs (like circular practices, resilience capabilities, performance metrics) and their relationships, which future analytical or simulation models can formalize and test.

Second, this work contributes by highlighting the role of time and dynamics in sustainable operations management. Traditional sustainability research often looks at steady-state improvements (reducing footprint, etc.), while resilience research emphasizes dynamic response and recovery. By marrying the two, we underscore that sustainability (circularity) is not just a static goal but also a dynamic capability – for example, the ability to continually cycle resources is a dynamic trait that affects how a system responds over time. This perspective can enrich theory by introducing feedback loops and temporal dimensions into sustainable SCM models (for example, considering how the frequency and speed of recycling cycles might influence the speed of recovery after a disruption). The notion of temporal trade-offs (short-term efficiency vs. long-term resilience payoff) also emerges, which can be examined through inter-temporal choice theories in operations management. Third, on a methodological note (though not purely theory), our review surfaces the need for integrative methodologies (mixed-method, multi-criteria, multi-level) to study CE–SCR phenomena. This indicates an epistemological broadening – encouraging researchers to go beyond single-discipline methods and combine qualitative insights with quantitative models to capture the full complexity of circular–resilient systems. In doing so, new theory can be built that is empirically grounded in both "hard" data (e.g., performance metrics, network models) and "soft" data (e.g., managerial perceptions of trade-offs, cultural factors).

VII. PRACTICAL IMPLICATIONS

For practitioners – supply chain managers, sustainability officers, and policymakers – our findings carry several important implications.

1) Strategic Alignment of Goals: Companies should explicitly align their sustainability (circular economy) initiatives with their risk management and resilience strategies. Rather than treating these as separate agendas (often handled by different departments), leading firms will integrate them under a common supply chain strategy. For instance, when evaluating a new circular program (like a product take-back scheme), managers should assess not only the environmental and cost impact, but also how it can improve supply continuity or flexibility. Conversely, when devising business continuity plans, they should consider if circular practices (like alternative sourcing from recyclers or using reusable packaging) could enhance those plans. This integrated thinking ensures that investments yield dual benefits and that efforts in one domain (CE or SCR) support the objectives of the other.

2) Adopt "No-Regrets" Practices: The review identified certain "no-regrets" practices – i.e., actions that are beneficial from both sustainability and resilience standpoints with little downside. Managers would be wise to prioritize these. Examples include: modular product design, which as discussed makes both recycling and repair easier; diversification of sourcing including secondary (recycled) materials, which hedges against supplier risk while closing material loops; predictive maintenance and life-cycle extension, which cuts waste and also prevents disruptions from equipment failure; and collaborative partnerships in the supply network, which spread both the gains of circularity and the burden of disruption response. Adopting such practices can yield immediate improvements in efficiency or innovation, and pay off in future crises. Essentially, these are strategies that enhance operational robustness and sustainability simultaneously – making them low-regret, high-return options.

3) Build Collaborative Networks and Platforms: A practical takeaway is the importance of supply chain collaboration mechanisms. Managers should invest in building trust and information-sharing platforms with suppliers, customers, and even competitors (in pre-competitive consortia) to facilitate circular flows and mutual aid in disruptions. For instance, manufacturers might create a shared database of spare parts or recycled material availability that all partners can draw on during shortages (Cobra et al., 2023). Industry groups or circular economy hubs can serve as nodes of coordination. The implication is that the old paradigm of arm's-length transactions is less effective in a world where both sustainability and resilience require deeper integration of activities across firms. Managers should cultivate long-term partnerships, possibly formalized through contracts that include clauses on circular economy collaboration and risk-sharing. Policymakers, too, can aid this by encouraging industry ecosystems (e.g., eco-industrial parks, as exist in some countries, where companies physically collaborate by using each other's waste streams) as a way to bolster regional resilience.

4) Invest in Technology and Data Analytics: The findings make it clear that digital transformation is a key enabler. Managers should evaluate technologies like blockchain for traceability of materials (to certify recycled content and quickly identify supply chain anomalies), IoT for real-time monitoring of product usage and returns, and AI for predictive analytics on supply chain disruptions and return flow patterns. These technologies can provide the visibility and agility needed to operate a circular supply chain and respond swiftly to disruptions (Wang et al., 2020). That said, technology adoption should be guided by a solid business case – our review suggests the business case can be strengthened by factoring in both sustainability and resilience benefits. For example, an IoT system might be justified not just by inventory accuracy improvements but also by the value of early warnings it provides for disruptions (a resilience benefit). Policymakers and industry associations might support small and medium enterprises in this tech adoption, given that many such firms find it challenging to implement advanced systems on their own.

5) Measure Dual Outcomes: Practitioners should expand their performance measurement systems to capture both circular and resilience outcomes. This could mean augmenting existing dashboards with metrics like *% of materials recycled*, waste-to-landfill reduction (for circularity) alongside supply chain risk KPIs like *time-to-recovery*, and then observing how strategies impact both sets of metrics. Over time, data collected on these metrics can help quantify the ROI of circular–resilient initiatives (e.g., *"our remanufacturing program contributed X dollars in avoided downtime during the last disruption"*). Regulators or certification bodies may also develop standards for reporting circular–resilience performance, which would further incentivize companies to track and improve in this area.

For policymakers, an implication is that policies fostering circular economy (recycling infrastructure investments, extended producer responsibility laws, etc.) can also enhance national or regional supply chain resilience. This provides an additional justification for such policies beyond environmental benefits. For example, governments might support local recycling of critical materials (like rare earth elements) not only to reduce waste but to ensure a domestic supply source if imports are cut off – effectively treating recycling as a matter of **economic resilience**. Similarly, policies that encourage modular design and **right-to-repair** will yield resilience dividends by making economies less vulnerable to supply disruptions of whole products, since components can be repaired or substituted more easily.

VIII. RELATION TO EXISTING FRAMEWORKS

Our findings reinforce and extend existing supply chain management frameworks. For instance, the classic SCOR model (Supply Chain Operations Reference) might be augmented to include reverse flows and risk management explicitly, reflecting circular and resilience considerations. The Triple Bottom Line concept is enriched by adding the dimension of resilience as a connector between economic and environmental performance (some have argued for a "quadruple bottom line" including resilience or governance). In the sustainability literature, concepts like Closed-Loop Supply Chain Management (CLSCM) are well established; we add that resilience considerations should be embedded in CLSCM design. In the resilience literature, frameworks of supply chain resilience enablers (e.g., flexibility, redundancy, visibility, collaboration) – we show that each of these enablers can be achieved in part through circular strategies (e.g., redundancy via secondary resource loops, visibility via tracking of returns, etc.).

One particular theoretical synergy is the alignment with Resource Dependence Theory and the idea of resource security. CE reduces dependence on virgin resources, which in theory reduces exposure to external supply shocks – a very direct overlap with resilience thinking (which often uses resource dependence logic to explain why firms suffer in disruptions). We effectively see CE as a strategy to mitigate resource dependence risks. Our review provides empirical support for this argument (like Gaustad et al., 2018 on critical minerals, Paul & Saha, 2025 on product supply).

Another point is how socio-technical systems theory might view CE–SCR integration: supply chains are socio-technical systems, and CE adds new social (stakeholder engagement in recycling) and technical (new technologies and processes) elements that change system behavior. Some of the interdisciplinary issues noted (Rasi et al., 2023) show that one must integrate social, environmental, and technical considerations simultaneously – something future research should address, likely requiring cross-disciplinary collaboration beyond the traditional operations management realm (involving environmental science, sociology, public policy, etc., as needed).

IX. LIMITATIONS

It is worth acknowledging limitations in both the literature and our review. The existing literature is still biased towards conceptual and qualitative studies, with relatively few large-sample empirical studies demonstrating the CE–resilience relationship (exceptions include some simulation and optimization works, and a handful of surveys). This means many assertions (e.g., *"CE improves resilience"*) are based on case observations or logical inference, but large-scale statistical evidence remains limited. Moreover, there is a potential *survivor bias* in case reporting – successful cases of circular–resilient integration get published, while failed attempts might not, skewing the perspective toward positive outcomes. Our review tried to capture challenges to counterbalance this, but as more data-driven research emerges, the understanding may evolve.

Our SLR methodology, while rigorous, also has limitations: by focusing on explicit CE–SCR intersection papers, we might have omitted some relevant insights from broader sustainability or risk management literature that didn't use our specific keywords. We mitigated this by broad searches and including some tangential references in the discussion, but it's possible that useful concepts (e.g., from general disaster management or from circular business model research not linked to SC) could inform this topic. Another limitation is that our analysis did not deeply segregate findings by industry or region due to space; in reality, the applicability of certain practices can be context-dependent (what works for a high-tech electronics supply chain might differ for an agricultural one). We flag this as a future research need – context-specific studies.

Finally, measuring resilience is inherently tricky (since it's about potential performance in future disruptions). Many studies had to simulate scenarios or use proxies, which is a limitation of empirical validation in this domain. This again points to future work where real-world data from disruptions (like lessons from COVID-19 or other crises) could be systematically analyzed as evidence.

Despite these limitations, this review offers a timely synthesis with actionable insights, at a moment when companies worldwide are grappling with how to rebuild supply chains for greater sustainability and resilience post-pandemic. Next, we present a set of targeted future research directions to spur further investigation and address the gaps identified.

X. FUTURE RESEARCH DIRECTIONS

Building on the gaps and open questions highlighted by our review, we propose several future research directions. These are structured to address conceptual gaps (where understanding is nascent), empirical gaps (where evidence is lacking or mixed), and methodological gaps (where new approaches are needed).

1) Develop integrated performance measurement systems for circular–resilient supply chains. *Research question:* How can we measure success across both circularity and resilience in supply chains? Gap: Lack of unified metrics combining CE and SCR outcomes – few studies offer frameworks that jointly evaluate environmental, circular, and resilience performance (Le et al., 2025). Rationale: To guide and justify integration efforts, firms need composite indices or dashboards (e.g., a "circular resilience scorecard"). Future research can propose and validate metrics like "percentage of supply from secondary sources during disruptions" or "recovery time improvement per unit increase in circularity." Such metrics would help quantify trade-offs and synergies. *Illustrative references:* Le et al. (2025) noted the need for integrated performance metrics; Paul and Saha (2025) stress measuring resilience improvement from CE strategies.
2) Investigate upstream supply network collaboration and multi-tier circular–resilience strategies. *Research question:* How can suppliers and entire multi-tier networks be engaged in CE–SCR initiatives? Gap: Upstream (supplier) involvement in CE–SCR is underexplored – most studies focus on focal firms or downstream recovery, with limited examination of supplier-side dynamics (Le et al., 2025). Rationale: Future research should examine how multi-tier supplier partnerships (e.g., raw material suppliers investing in recycling, suppliers sharing risk in circular investments) contribute to resilience. This could involve case studies or surveys on supplier engagement, incentive alignment (e.g., contracts that reward circularity and reliability), and the role of lead firms in orchestrating network-wide circular–resilient practices. *Illustrative references:* Le et al. (2025) identified upstream collaboration as a gap; Rasi et al. (2023) discussed interdisciplinary challenges including across supply tiers.

3) Examine dynamic and temporal effects of circular initiatives on resilience (longitudinal studies). *Research question:* How do circular practices impact resilience over time and across different disruption scenarios? Gap: Most current studies are static or snapshot analyses. The temporal dynamics between implementing CE and realizing resilience benefits (or costs) are not well understood (Le et al., 2025). Rationale: Longitudinal research could track firms over time as they adopt circular practices and encounter disruptions, to see how resilience evolves. Simulation and system dynamics modeling could explore scenarios (e.g., if circular adoption is gradual vs. rapid, how does the risk profile change?). Additionally, research can consider whether initial investments in CE may temporarily reduce resilience (due to learning curves or reconfiguration) before yielding net benefits – a potential short-term vs. long-term trade-off to study. *Illustrative references:* Le et al. (2025) call for examining temporal dynamics of circular–resilient strategies. Ivanov's work (e.g., Ivanov, 2020) suggests dynamic "ripple effect" analysis for closed-loops; Paul & Saha (2025) highlight need for scenario-based validation of CE benefits under disruptions.

4) Leverage digital technologies and Industry 4.0 for CE–SCR integration. *Research question:* What is the role of advanced technology in enabling circular–resilient supply chains, and how can it be effectively implemented? Gap: While many authors mention technology enablers, empirical research on specific technologies (IoT, blockchain, AI, digital twins) in the CE–SCR context is scant. It's unclear which technologies yield the greatest impact or how to implement them effectively. Rationale: Future studies should investigate, through pilots or case studies, how *blockchain* for traceability of recycled materials improves trust and agility (Wang et al., 2020), or how *AI-driven demand and return forecasting* can reduce uncertainty in closed-loop systems. Measuring the effect of digital interventions on both circular outcomes (e.g., increased recovery rate) and resilience outcomes (e.g., faster response to recalls) would be valuable. This could also involve optimization models that integrate IoT sensor data to dynamically re-route reverse logistics during disruptions. *Illustrative references:* Wang et al. (2020) illustrate blockchain enabling circular & resilient fast fashion supply chains; Chari et al. (2022) noted Industry 4.0 enhances dynamic capabilities for CE–resilience. Dubey et al. (2021) call for research on Big Data analytics in sustainable–resilient SCM.

5) Explore context-specific applications: emerging economies and sectoral studies using holistic methods. *Research question:* How do CE–SCR strategies vary by context (developed vs. emerging economies, or by industry sector), and how can mixed-method approaches provide deeper insights? Gap: Much research is from developed economies and manufacturing sectors. Contexts like emerging economies (with infrastructure constraints) or sectors like agriculture, healthcare, etc., are understudied in CE–SCR integration (Le et al., 2025). Also, many studies use single methods; integrated approaches (combining qualitative and quantitative) are rare (Rasi et al., 2023). Rationale: Future work should examine, for example, textile supply chains in developing countries – how can circular practices (e.g., recycling fabric, employing repair artisans) improve resilience to market and climate shocks in those contexts? Such settings may reveal different drivers (e.g., social enterprises, informal recycling networks) and barriers (e.g., lack of formal waste systems). Employing mixed methods – e.g., fuzzy multi-criteria decision models to prioritize strategies, followed by scenario-based simulations to test their robustness – can yield actionable insights for those contexts (Faisal & Talib, 2016; Negri et al., 2021). This also helps validate conceptual frameworks in varied settings and ensures recommendations are not one-size-fits-all. *Illustrative references:* Some emerging studies (e.g., Chowdhury et al., 2021) underscore context-specific factors for resilience in developing countries; Negri et al. (2021) point to the need for sector-specific analysis. Mixed-method exemplars in SCM (Faisal & Talib, 2016) show the value of combining multi-criteria analysis with simulation for strategy development.

Table 3: Summary of Future research directions for integrating Circular Economy (CE) and Supply Chain Resilience (SCR). Each direction is linked to specific gaps identified in the literature and suggests avenues for investigation.

Research gap	Specific research questions	Suggested methods	Priority/ feasibility	Illustrative references
Integrated CE–SCR performance metrics (including "circularity continuity")	How should resilience be measured when systems must maintain both service continuity and circular functions (collection, recovery, remanufacturing)? What trade-offs emerge among recovery time, service level, profitability, and circularity rate?	Metric development + validation; multi-criteria decision analysis; simulation comparing candidate indices	High / Medium (conceptual + empirical validation required)	(Le et al., 2025; Cafforio et al., 2025; de Arquer et al., 2022)
Returns uncertainty as a resilience risk factor	Which uncertainty sources (return rates, grading quality, reverse lead-time	Stochastic/robust optimization;	High / Medium	(Goltsos et al., 2019; de Arquer

Research gap	Specific research questions	Suggested methods	Priority/ feasibility	Illustrative references
(quality/quantity/timing)	variability) most degrade resilience? What control policies reduce amplification while retaining circular benefits?	system dynamics; empirical calibration from reverse-logistics data		et al., 2022)
Upstream collaboration & incentive alignment in circular-resilient systems	Which contracts/incentives make upstream suppliers and recovery partners share risk, capacity, and information? How do incentives differ between open-loop vs closed-loop take-back designs?	Contract theory + game models; multi-case studies; survey/SEM for governance constructs	High / Medium–Low (data access across tiers is hard)	(Le et al., 2025; Cafforio et al., 2025)
Digitalization pathways: when does tech enable circular-resilient reconfiguration?	Do analytics/traceability improve SCR *directly*, or mainly through enabling CE practices (mediation/moderation)? Which technologies matter most for reverse-flow visibility?	PLS-SEM with mediation; quasi-experiments; digital twin / scenario analytics	High / Medium	(Islam et al., 2025; Wang et al., 2020; Chari et al., 2022)
Disruption-ready circular omnichannel design	How should omnichannel networks jointly design forward and reverse flows for disruption preparedness, not just sustainability compliance?	Multi-objective MILP with disruption scenarios; real-case validation; stress testing	High / Medium	(Torshizi et al., 2026)
Emerging economy and SME constraints in CE–SCR adoption	Which CE strategies are most resilience-effective under limited capital, informal recovery markets, and infrastructure constraints? What "minimum viable" circular-resilient capability sets exist?	Comparative multi-country surveys; mixed-method case studies; configurational methods (fsQCA)	High / Medium	(Aming'a et al., 2024; Islam et al., 2025)
Circular network topology and structural resilience	How do network structures (centralized vs distributed recovery hubs; open vs closed loops) affect robustness and recovery after facility or transport disruptions?	Network science + optimization; agent-based modeling; resilience "stress tests" using topology perturbations	Medium / Medium	(Jabbarzadeh et al., 2018; Vali-Siar et al., 2022)
Sector-specific CE–SCR mechanisms and external validity	Which CE–SCR link mechanisms generalize across sectors (healthcare vs food vs apparel), and which are sector-specific (regulation, shelf-life, criticality)?	Cross-sector meta-synthesis; standardized case protocol; replication logic	Medium / Medium–Low	(Cobra et al., 2023; Fletcher et al., 2021; Torshizi et al., 2026)

These directions are by no means exhaustive, but they represent high-impact avenues that can collectively advance this field. In particular, empirical research (through surveys, longitudinal case studies, and secondary data analysis) could validate many of the assumed benefits of CE–SCR integration and uncover any boundary conditions. For instance, is there a threshold of circularity beyond which additional resilience gains diminish or even reverse? Are there cases where circular strategies have failed to deliver resilience, and why? These questions remain open. Additionally, experimental and simulation studies can explore scenarios that real life cannot easily isolate – for example, to understand non-linear dynamics: *How does variability of returns interact with severity of disruptions? Under what conditions might circular strategies inadvertently create new risks, and how can design or policy mitigate that?*

Another promising direction is exploring the **human and organizational behavior** aspect in CE–SCR. Change management, organizational culture, and leadership perspectives could be key – implementing circular practices often requires cultural shifts, and resilient organizations often credit culture ("resilience culture") for their success. Investigating how an organizational culture that values sustainability might correlate with proactive resilience behaviors would be insightful. Similarly, examining the role of leadership in championing both circular and resilient thinking could reveal important best practices.

Cross-disciplinary research is encouraged. For example, collaboration with environmental scientists can help quantify how much resource security (resilience) is improved by certain circular practices (like *how much does recycling 1 ton of a critical material reduce supply chain disruption risk?* – bridging to risk modeling). Collaboration with economists could better model incentives and market mechanisms for circular–resilient practices (like trading of secondary materials under disruption scenarios, or insurance products for circular assets).

Ultimately, by pursuing these research directions, scholars can help create a more robust theoretical foundation and clearer practical guidelines at the CE–SCR interface. The need for such knowledge is urgent as businesses and governments seek ways to "build back better" (and greener) in the wake of global disruptions.

A. Multi-method Approach for Studying CE–resilience Strategies

A methodological flowchart is presented in Figure 2 to illustrate an example of a multi-method approach for studying CE–resilience strategies (as suggested in emerging research).

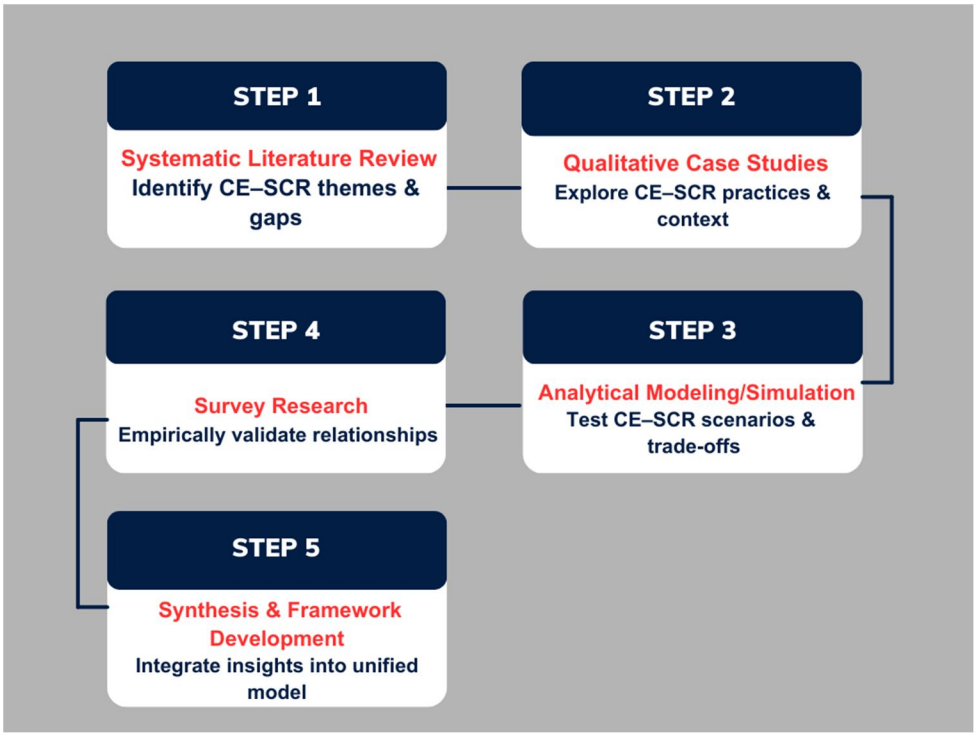

Figure 2. Proposed multi-method research flowchart for studying CE–SCR linkages.

This methodological framework outlines a stepwise, multi-method approach: (1) begin with a Systematic Literature Review (SLR) to map existing knowledge, identify key themes, and uncover research gaps in the CE–SCR domain; (2) conduct qualitative case studies with firms or supply chains to gain in-depth contextual insights into how circular practices and resilience capabilities interact in real settings; (3) use analytical modeling or simulation to test specific scenarios or mechanisms (e.g., the effect of circular inventory strategies on disruption outcomes), allowing controlled analysis of CE–SCR dynamics; (4) perform survey-based empirical research to validate and generalize findings across a broader sample of industries or regions, statistically examining the relationships between CE adoption, resilience measures, and performance; and (5) finally, synthesize the insights from these methods to develop an integrated framework or theory that links CE and SCR. Employing such a mixed-method approach provides both depth and generalizability, yielding a comprehensive understanding of how circular economy initiatives can contribute to supply chain resilience and under what conditions.

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XI. CONCLUSION

This paper set out to review and analyze the burgeoning area at the crossroads of circular economy and supply chain resilience. Through a systematic literature review encompassing approximately two decades of research, we have provided a comprehensive synthesis of how circularity and resilience concepts interact in supply chain contexts. The evidence is compelling that circular economy principles – designing out waste, keeping materials in circulation, and regenerating natural systems – can be strategically leveraged to enhance supply chain resilience by reducing resource dependencies and increasing adaptive capacities. We documented numerous cases and studies where circular practices (from recycling to remanufacturing to collaborative waste re-utilization) enabled supply chains to better absorb and recover from disruptions, whether those disruptions were demand surges, supply shortages, or global crises.

At the same time, our review candidly highlights that achieving the twin goals of circularity and resilience is not automatic; it requires navigating trade-offs and thoughtfully redesigning supply chain operations. Challenges such as managing the uncertainty of reverse logistics, balancing efficiency with buffers, and coordinating across extended supply networks must be addressed. We identified a set of integrated practices – including innovative product design, process improvements, network reconfiguration, strong collaboration, and digital technologies – that serve as enablers to jointly optimize for circularity and resilience. These practices form the basis of a framework (Figure 1) that future enterprises can adopt as a blueprint for **Circular Supply Chain Management (CSCM)** aligned with resilience objectives.

From a theoretical standpoint, this work contributes to a more holistic understanding of sustainable operations by linking two previously siloed research streams. It underscores that sustainability and resilience are complementary aspects of the broader pursuit of supply chain sustainability – resilient supply chains are more likely to be sustainable over the long run, and sustainable (circular) supply chains inherently cultivate forms of resilience. We encourage scholars to further develop this integrated perspective, employing new lenses and methods to deepen knowledge, as outlined in our future research agenda (Table 3). In particular, we stress the need for empirical validation and longitudinal studies to move beyond qualitative rationale to quantitative proof of the circular–resilient value proposition.

For practitioners and policymakers, the implications are actionable. Investing in circular economy initiatives can yield resilience dividends, making supply chains not only greener but also more secure and stable. Conversely, approaching resilience planning with an eye to circular opportunities can unlock innovative solutions that also advance sustainability goals. Companies that have been pioneers in this space demonstrate that far from being a trade-off, circularity and resilience can create a virtuous cycle: resilience ensures the continuity needed to achieve sustainability targets, and circularity provides the resources and flexibility needed to be resilient. Policymakers can amplify this by crafting regulations and incentives that jointly promote environmental responsibility and supply chain preparedness – for example, supporting local remanufacturing not just for jobs or waste reduction, but as a matter of economic resilience.

In closing, the integration of circular economy and supply chain resilience is not just a theoretical ideal but an increasingly practical imperative. The events of recent years have shown that global supply chains face complex risks that require more creative, regenerative approaches to management. Meanwhile, the urgency of climate change and resource depletion calls for transformative change in how supply chains operate. The circular economy provides a pathway for that transformative change, and when combined with resilience thinking, it offers a route to supply chains that are not only sustainable in good times but also robust in the face of adversity. We hope this review contributes a solid foundation of knowledge and inspiration for both academics and practitioners to accelerate the transition toward circular, resilient supply chain ecosystems that can thrive in the uncertain years ahead.

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[44] ChatGPT (OpenAI, 2026) was used to assist in summarizing background literature to support understanding from published research articles for this review, and it was utilized only for this purpose. The author independently read and verified all cited sources and ensured that summaries accurately reflected the original texts.

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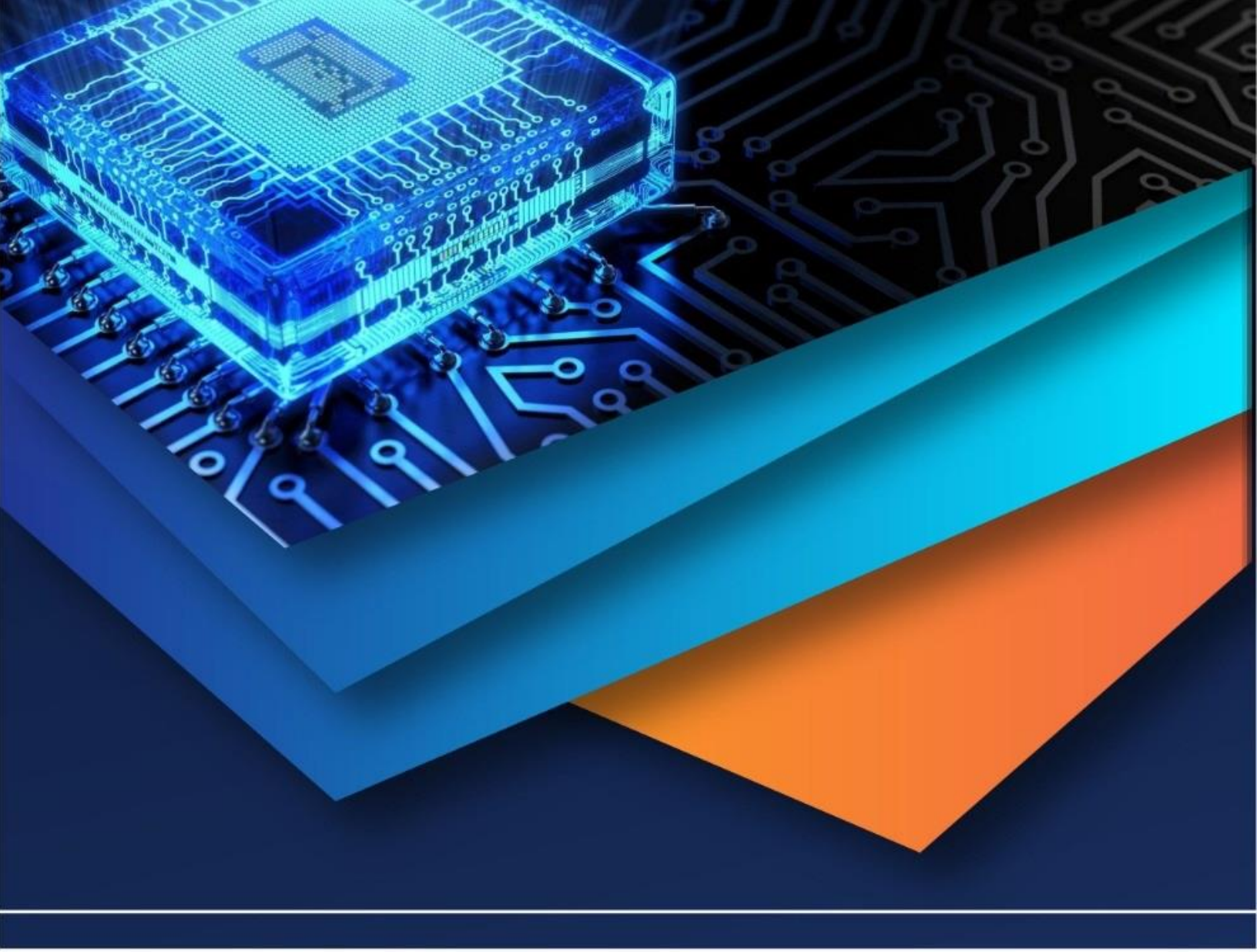

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